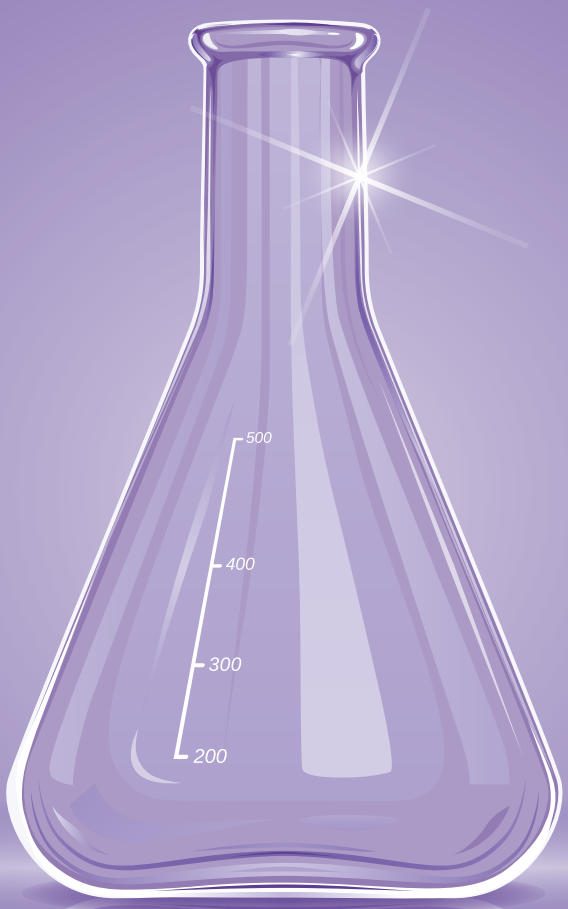

Laboratory glassware reprocessing

Safe and residue-free reprocessing of laboratory glassware

Introduction

As the majority of processes in the laboratory are already regulated and documented, it is astonishing that to date sufficient attention has not been given to laboratory glassware reprocessing either in the literature or in standardisation work. This may be due to the fact that optimal reprocessing of laboratory glassware requires specialist knowledge from a range of different disciplines. This booklet was produced by the **laboratory glassware reprocessing working group (AK LAB)**. It compiles the collected specialist knowledge of leading manufacturers of laboratory glassware, process chemicals and lab washers as well as of quality assurance experts and users for the very first time.

The mechanisms of action and influencing factors that need to be taken into consideration when reprocessing laboratory glassware are explained using simple examples.

The information and checklists provided should offer the users safety when planning the reprocessing of their laboratory glassware and selecting the process chemicals as well as the laboratory glassware and laboratory equipment to be used.

There is one simple rule: Precise measurements and analysis results are only possible once the cleanliness of the equipment used has been determined and ensured.

The working group likes to make a contribution to this.
We wish you consistently pristine results!

AK LAB

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1 Material selection:

Glass, plastic, metal, porcelain laboratory ware and their design

A range of different materials each with different properties is used in laboratories. Each time it is either down to the qualified laboratory personnel to decide which material to use for which process or the material has been documented and bindingly established by the quality assurance officer in work instructions or a SOP (standard operating procedure).

Generally speaking, a distinction is made between laboratory glassware and laboratory equipment, with the latter forming a group of containers and aids made of different materials such as plastic, porcelain and metal and for which different cleaning recommendations apply accordingly. This booklet focuses on the automated reprocessing process of laboratory glassware. All the materials used as standard in laboratories are described in more detail below for the sake of completeness.

Borosilicate glass 3.3 Erlenmeyer flask

1.1 Materials, temperature resistance, chemical resistance

Borosilicate glass 3.3 as regulated by the DIN ISO 3585 standard is used in laboratories whenever high chemical and thermal resistance is required of a reaction or storage vessel during analytical or reaction processes. Laboratory glassware made of borosilicate glass 3.3 is predominantly used in chemical analytics because the user depends on the high transparency of the material for being able to notice changes in the colour or other properties of the substance being analysed. Due to the minimal thermal expansion of the material, the majority of devices for determining volume (e.g. volumetric flasks, measuring cylinders) are also made of borosilicate glass 3.3.

All in all it can be determined that borosilicate glass 3.3 has become a universal material for many laboratory applications thanks to its high inertness as well as its mechanical and thermal resistance. These properties are also beneficial for the vessels with regard to the reprocessing process. When handled correctly, laboratory glassware made of borosilicate glass 3.3 can be reprocessed as often as desired and as such makes a considerable contribution to the cost-efficient and sustainable operation of the laboratory.

Soda-lime glass reagent bottle

Fused quartz crucible

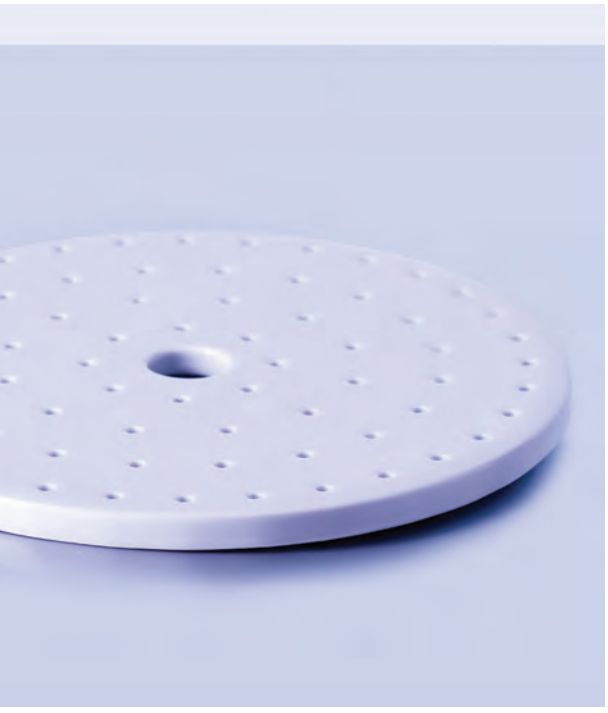
In addition to borosilicate glass 3.3 there are numerous other types of glass with different properties available for use in laboratories. For example, different varieties of soda-lime glass are used for storing powders and solid substances. Soda-lime glass is also employed as a material for pipettes. However, due to the high thermal expansion of soda-lime glass – compared with borosilicate glass 3.3 – its resistance to temperature changes is low, especially during the automated reprocessing process. For this reason, it is generally advised to avoid using soda-lime glass for work where heat is applied or hot liquids are added. Soda-lime glass vessels sometimes provide a cost-effective alternative to borosilicate glass 3.3 for short-term storage requirements.

Fused quartz is occasionally used in laboratories. It is characterised by outstandingly low thermal expansion, high temperature resistance (up to 1,000 °C) and extremely high UV permeability. Items made of fused quartz are frequently cuvettes, small beakers, Erlenmeyer flasks, crucibles and custom-made products. As they are expensive to purchase, laboratory glassware items made of fused quartz are used comparatively seldom.

In addition to laboratory glassware, plastic has been able to establish a position for itself as a material for vessels and accessories in the laboratory. This is predominantly because there is simply no single universal material which can satisfy all the requirements of laboratory work. The decision of using glass or plastic is based upon the intended application and product design, while taking into account the specific properties of these materials and cost-efficiency aspects. When talking about plastic laboratory goods, one distinguishes between disposables and reusables. Disposables are not discussed in any further detail below, as they are not reprocessed for use in laboratories. Plastic laboratory goods can display a huge variety of properties. At the same time, the range of varieties available for this material is considerably broader than for the different types of glass, for example. Thanks to the considerably lower risk of breakages and their significantly lighter weight, plastics are preferred to glass for use as transport containers.

1

Plastic measuring cylinder



Porcelain dessicator insert

In contrast to metals, many plastics, due to their organic nature, are resistant to inorganic media. This includes mineral acids, lyes and aqueous saline solutions. However, in contrast to metals, they often react sensitively to organic solvents. Unlike glass, which is almost universally employable, it is always essential to consider the specific properties of the individual types of plastic when using laboratory plastics.

In addition to the materials already listed above, porcelain laboratory ware in accordance with DIN EN 60672-3, Type C110 is used. Vessels and accessories made of hard porcelain are characterised by their outstanding deformation resistance (up to 1,000 °C), corrosion resistance, mechanical stability and durability. Products made of laboratory porcelain are often used as aids in analytical and preparation work.

1.2 Design

The product spectrum of laboratory glassware is very extensive to suit users' requirements to the greatest possible extent. They not only differ in terms of their shapes and functions, but also in their volumes. Laboratory glassware is available in a volume range from 5 ml to 50,000 ml. Laboratory glassware items which cannot be reprocessed automatically due to their dimensions and shapes must be cleaned manually.

They are generally divided into:

- **Reaction vessels**, such as beakers, Erlenmeyer flasks, round-bottomed flasks and test tubes
- **Containers** for preservation, storage and transport, such as laboratory bottles, reagent bottles, culture tubes, which are characterised by a seal (glass stopper or screw cap)

- **Volumetric glassware**, such as volumetric flasks, measuring cylinders, measuring pipettes and burettes which are equipped with precise scales / graduation markings
- **Glass filtration apparatus**, such as filter funnels
- **Interchangeable glassware**, such as condensers and multi-neck flasks, which are used to connect pieces of apparatus

The vastly different volumes of the laboratory glassware and laboratory equipment used in the laboratory alone make it impossible to issue universal cleaning instructions.

The following information should be used as a guide:

The appropriate volume already should be taken into account when selecting the laboratory glassware. Laboratory glassware with a corresponding small volume is used for small samples. The use of laboratory glassware with complex shapes, e.g. back tapers, dead spaces, etc., should be avoided as these require increased cleaning efforts. In automated reprocessing there should be used load carriers (mobile units, baskets, inserts) which are offered by manufacturers of lab washers adapted for different products.

1.3 Selection criteria for specific applications / summary

Particular criticism should be exercised when selecting the ideal material for the application and consequently the correct reprocessing method. Laboratory glassware made of borosilicate glass 3.3 can be employed universally and, with very few exceptions, without any limitations. The majority of laboratory glassware items are regulated by international standards and have already been used millions of times as well as being, in comparison with other materials, relatively simple to reprocess. Manufacturers of lab washers offer a wide range of load carriers to achieve optimal reprocessing results for laboratory glassware with different shapes.[1]

2 Process chemicals

Process chemicals are chemical formulations used for the manual and automated reprocessing of laboratory glassware and laboratory equipment.

This booklet refers to the process chemicals in general as “process chemicals” and specifically as “cleaning agents”.

2.1 Types of process chemicals

Cleaning agents:

Cleaning agents dissolve and remove contaminants from surfaces of laboratory glassware and laboratory equipment. An additional function of cleaning agents is to prevent renewed deposition of the dissolved and removed contaminants on the laboratory glassware and laboratory equipment and in the lab washer.

Generally, cleaning agents can be divided into:

- Highly alkaline cleaning agents
- Mildly alkaline and alkaline cleaning agents
- Mildly alkaline and alkaline cleaning agents with surfactants
- Mildly alkaline and alkaline cleaning agents with oxidising agents
- Neutral cleaning agents with surfactants
- Acidic cleaning agents
- Acidic cleaning agents with surfactants

Neutralisers:

Neutralisers are acidic with an inorganic or organic acid basis and are used to neutralise alkaline cleaning agent residues on surfaces of laboratory glassware and laboratory equipment and in the circulation system of the lab washer.

Additional components:

Additional components are generally dosed together with the cleaning agent in order to boost the effect of the cleaning agent (e.g. wetting of the surfaces of laboratory glassware and laboratory equipment or oxidisation of contaminants), to better collect contaminants in the water (e.g. emulsification, dispersing) or to compensate the negative properties of the contaminants (e.g. defoaming).

General categories of additional components:

- Surfactants / emulsifiers
- Oxidation agents
- Defoaming agents

2.2 Properties and assessment of constituent substances

Constituent substance	Properties
Active chlorine / active oxygen	Strong oxidising and disinfecting effect
Caustic alkalis, e.g. sodium hydroxide / potassium hydroxide	Maceration and degradation of contaminants
Alkali silicates	Cleaning support due to alkaline effect and improvement of contaminant absorption capacity as well as prevention of corrosion (aluminium)
Chelating agents (e.g. MGDA, GLDA)	Complexation of water hardness (Ca/Mg) and other metal ions (Fe, Zn, etc.) and boost of the cleaning effect
Phosphates	Avoiding of calcareous deposits (Ca/Mg) and dispersion of contaminant particles
Polycarboxylates, phosphonates	Avoiding of calcareous deposits (Ca/Mg) and dispersion of contaminant particles, serve as phosphate substitutes
Non-ionic surfactants	Coating property, defoaming and emulsification of contaminant particles

2.3 Residue-free cleaning

The objective of every reprocessing process is “clean” / “analytically clean” laboratory glassware and laboratory equipment. Each laboratory has the task of defining the requisite degree of cleanliness for subsequent use depending on the respective application. Depending on the application, it may be necessary to avoid process chemicals with certain constituent substances for the reprocessing of laboratory glassware and laboratory equipment, as they could e.g. negatively influence analytical methods. One example is the use of phosphate-free process chemicals for laboratories which perform water analysis.

The process chemical manufacturer can provide a description of possible analysis methods for identifying process chemical residues on surfaces of laboratory glassware and laboratory equipment or in the last rinse water (final rinsing).

The analysis method can, for example, be based on certain constituent substances of the process chemicals, which can be analytically identified well with standard methods and are contained in the process chemicals in considerable quantities (e.g. phosphates).

2.4 Dosing and dosing technology

Generally speaking, process chemicals can be employed in both powder and liquid form. Powdered process chemicals are dissolved after being added to the lab washer, whereas liquid process chemicals are already available in dissolved form. Powdered process chemicals are almost exclusively cleaning agents.

As they can be dosed automatically, liquid products should be given preference. This type of dosing is advantageous in terms of dosing precision and monitoring.

A decisive factor contributing to good reprocessing results is the precise control of dosed chemicals.

Powdered cleaning agents should be sealed carefully after use, as they can otherwise clump together when exposed to air humidity due to hygroscopic constituent substances.

Depending on the on-site conditions decentralised or centralised dosing is possible. Centralised, external dosing is more practical if several lab washers within a building complex are operated with one and the same process chemical, e.g. via storage vessel.

In contrast, if several individual lab washers are operated with different process chemicals, perhaps even with liquid and powdered process chemicals, decentralised dosing is more practical. In this respect, each department must ensure that the dosing is performed correctly and that regular checks are conducted.

When dosing process chemicals with surfactants, consideration must be given to the temperature and time of dosing. Non-ionic surfactants have a so-called cloud point at a certain temperature. When dosing process chemicals, the temperature should be above the cloud point to ensure that there are no foaming problems. Referring to this, the instructions provided by the process chemical manufacturers in the product-specific documentation must be taken into consideration.

In certain conditions, process chemicals with active chlorine or active oxygen can have a gassing tendency. These conditions include, for example, increased temperatures (room temperature / storage temperature / transport temperature). For this reason, these process chemicals are equipped with a ventilation seal to avoid pressure build-up and swelling of the package.

In particular, attention must be paid to not confuse the packages and suction lances, as this could trigger chemical reactions, e.g.:

- Mixing of acidic and alkaline process chemicals: Severe heating
- Mixing of acidic process chemicals and process chemicals containing silicates: Flocculation of silicic acid

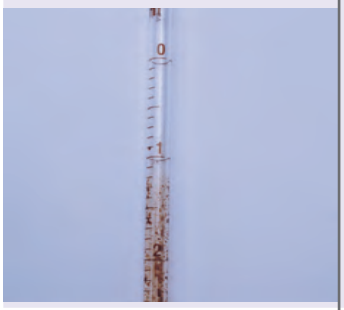
- Mixing of process chemicals containing phosphoric acid and citric acid: Crystallisation of citric acid
- Mixing of acid and process chemicals containing active oxygen: Severe gas formation
- Mixing of acid and process chemicals containing active chlorine: Formation of toxic gases (chlorine gas)

2.5 Selection criteria for specific applications

Each contamination must be viewed individually, nevertheless the following basic recommendations can be offered for the selection of process chemicals:

Contaminant	Process chemicals to be used		
	Pre-cleaning	Cleaning	Neutralisation
Water-soluble residues	Preferably water, no process chemicals required	Alkaline cleaning agent	Based on phosphoric acid or citric acid
Marker labelling 	No process chemicals required	Highly alkaline cleaning agent	Based on phosphoric acid or citric acid
Label remnants	No process chemicals required	Alkaline cleaning agent with surfactants	Based on phosphoric acid or citric acid
Inorganic/organic mixed deposits (e.g. limescale and algae)	Acidic cleaning agent	Alkaline cleaning agent, alkaline cleaning agent with oxidising agents for algae	Based on phosphoric acid or citric acid
Inorganic residues	Acidic cleaning agent	Alkaline cleaning agent	Based on phosphoric acid or citric acid

Contaminant	Process chemicals to be used		
	Pre-cleaning	Cleaning	Neutralisation
Organic residues	Preferably water, no process chemicals required	Highly alkaline cleaning agent	Based on phosphoric acid or citric acid
Microbiological residues	Preferably water, no process chemicals required	Alkaline cleaning agent with oxidising agent	Based on citric acid
Solid culture media	Preferably water, no process chemicals required	Alkaline cleaning agent	Based on phosphoric acid or citric acid
Liquid culture media	Acidic cleaning agent for culture media containing Ca or Mg	Depending on the composition Alkaline cleaning agent or alkaline cleaning agent with oxidising agent	Based on citric acid
Cell and tissue culture remnants, partly fixed by sterilisation	If applicable, alkaline cleaning agent with oxidising agent for pre-cleaning	Alkaline/ mildly alkaline cleaning agent with oxidising agent	Based on citric acid
Crude oil, mineral oils	Highly alkaline cleaning agent with surfactants and addition of an emulsifying component	Highly alkaline cleaning agent with surfactants	Based on phosphoric acid or citric acid
Creams, ointments	Alkaline cleaning agent with surfactants and addition of an emulsifying component, acidic pre-cleaning for zinc ointments	Alkaline cleaning agent with surfactants	Based on phosphoric acid or citric acid

Contaminant	Process chemicals to be used		
	Pre-cleaning	Cleaning	Neutralisation
Inorganic residues, partly fixed by sterilisation 	If applicable, alkaline cleaning agent with oxidising agent for pre-cleaning	Alkaline cleaning agent	Based on phosphoric acid or citric acid
Paraffin wax	Highly alkaline cleaning agent with addition of an emulsifying component	Highly alkaline cleaning agent with addition of an emulsifying component	Based on phosphoric acid or citric acid
Non-coagulated protein, e.g. blood	Preferably cold water, no process chemicals required	Alkaline cleaning agent	Based on phosphoric acid or citric acid

It must be taken into account that not only the process chemicals, but also for example the physical properties of the contaminants are decisive for successful cleaning.

Agar	The cleaning temperature must be selected so that the agar turns liquid again
Paraffin	The cleaning temperature should be selected high enough to melt the paraffin and keep it liquid throughout the entire cleaning process so that it does not deposit in the lab washer and on laboratory glassware and laboratory equipment
Non-coagulated protein, e.g. blood	Cold pre-cleaning to avoid the fixing of the contamination on the surfaces of the laboratory glassware and laboratory equipment

For more detailed information, please also refer to section 6 “Automated reprocessing”.

If laboratory glassware and laboratory equipment are employed for special analytical tests, the selection of the process chemicals should take the particularities of the analysis methods into consideration.

Analysis methods	Process chemicals which should not be used
Chemical analysis of phosphorus/phosphates, for example in water laboratories	Process chemicals with phosphates/phosphoric acid, as otherwise there is a risk of false results.
Trace analysis of organic substances and TOC	Process chemicals with surfactants (if possible), as, due to foaming, surfactants cause somewhat higher carryover and can adhere to the surfaces of e.g. plastic equipment.
Microbiological analyses	Process chemicals with surfactants, as the surfactants can impede the growth of microorganisms.

2.6. Storage

2.6.1 Legal basis

There is not one comprehensive legal regulation on the storage of hazardous substances, but rather a number of different directives describing different safety objectives such as the protection of soil and bodies of water, emission control, occupational and public safety, etc.

The following is a non-exhaustive list of important legal regulations to be observed:

- German Ordinance on Hazardous Substances (GefStoffVO)
- German Federal Water Act (WHG)
- German Regulations on Installations for Handling Water-Polluting Substances (VAwS)
- Technical Rules for Hazardous Substances (TRGS) - TRGS 510 Storage of hazardous substances in non-stationary containers

2.6.2 Principles for the storage of hazardous substances

As defined by the legal regulations concerning water, water-polluting substances are to be stored in such a way that it is not possible to pollute bodies of water or modify bodies of water in any way. The containers, equipment and premises used should be secured taking certain aspects into consideration:

- Storage facilities must be protected against unauthorised access. They must be airtight and resistant to the mechanical, chemical and thermal factors which can be expected
- Collecting rooms without drains
- Proper recycling and disposal of escaping water-polluting substances
- Existence of operating instructions for storage, including monitoring plan, material maintenance routeing and alarm plan

The term “storage” refers to stockpiling, but not to immediate use.

2.6.3 Storage of process chemicals

Hazardous substances also include process chemicals used for cleaning and disinfection purposes. There are different requirements for the storage of process chemicals depending on the water hazard class (WHC) and the total storage quantity. The water hazard classes are mostly listed in Section 15 of the safety data sheet.

Supply containers which are connected to lab washers or centralised dosing stations and contain quantities in excess of the daily requirement are also understood to be storage containers in the sense of legal regulations concerning water. The containers, equipment and premises used for storage must be secured accordingly.

Every stored hazardous substance is assigned to a storage class depending on its hazardous properties. This is of significance when it comes to the storage of hazardous substances. Hazardous substances in the same storage class should generally be stored in one storage section. The clustering storage of hazardous substances from different storage classes is currently described in detail in the table Separate or Clustering Storage in TRGS 510 and in the future in TRGS 509. Clustering storage is when different substances are stored in one storage section, a container, safety cupboard or a collection room.

Storage of acidic and alkaline products and products containing active chlorine

Products containing active chlorine in particular should be stored as cool as possible (0-25 °C) and protected from direct exposure to light as far as possible in well ventilated rooms. There is no specification for separating acidic cleaning agents and cleaning agents containing active chlorine, but it is recommended where possible due to the risk of the formation of chlorine gas if they were to come into contact.

As a general rule, the storage temperature should be below 30 °C, even for short-term storage. Direct exposure to sunlight and UV radiation should be avoided.

3 Water

3.1 The function of water in the reprocessing process

Water fulfils a variety of functions in the reprocessing process, e.g.:

- Solvent for various contaminants
- Solvent for process chemicals
- Conveyance of mechanics, temperature and process chemicals to the surfaces of the laboratory glassware and laboratory equipment
- Rinsing of dissolved, emulsified and suspended contaminants and employed process chemicals
- Medium for steam sterilisation

Unfavourable water composition can have an adverse effect both on the reprocessing process and on the appearance of the instruments and materials of the lab washers and the different laboratory glassware and laboratory equipment. For this reason, the provision of the process water in the necessary quality and sufficient quantity should be taken into account when planning water installations.

3.2 Constituent substances of drinking water

The type and concentration of the constituent substances in drinking water vary depending on the source of the water and how it is collected. All natural water contains dissolved ionic and non-ionic substances as well as undissolved particles.

The following water constituents may cause problems:

- Non-ionic compounds
  - Colloids (e.g. humic acids, irons)
  - Drug residues
- Ionic compounds
  - Minerals causing water hardness (calcium and magnesium ions)
  - Heavy and non-ferrous metals, e.g. iron, manganese, copper
  - Silicic acid, silicates
  - Chloride
- Particles
  - Rust particles

- Sand
- Pyrogenic particles (non-biological origin)

- Microbiological constituent substances
  - Bacteria, fungi, viruses and pyrogens

- Colloids (e.g. humic acids and iron)

Humic acids are highly molecular compounds which are produced in the degradation processes of biological materials. Water-containing humic acids are yellow in colour and can damage ion-exchanger resins via fouling for example. For this reason, they are removed in special procedures using activated charcoal filters or membrane processes (reverse osmosis), for example.

Colloidal iron can cause considerable problems in water reprocessing processes. If the iron is not removed from the water, it can cause corrosion among other things.

Drug residues

Drug residues are difficult to break down and accumulate in the water. Due to this accumulation, these substances are found in the water and nutrient cycles. The residues in the water can influence analytical methods (e.g. water, environmental, foodstuffs and pharmaceutical analysis) and applications with living organisms due to their toxicity / effect.

Minerals causing water hardness

Depending on water hardness and temperature, minerals causing water hardness can lead to the formation of a hard layer (lime deposits) that is difficult to dissolve. It is even possible for corrosion to occur underneath the deposit (galvanic element).

Heavy and non-ferrous metals

Heavy and non-ferrous metals and their compounds in the water can lead to red-brown or black scaling even at low concentrations. In disadvantageous cases, exchanger resins can even become inactive, e.g. as a result of copper ions, and consequently require replacing.

Silicic acid and silicates

Silicic acid and silicates may cause glaze-like, yellowish brown discolourations even at low concentrations and bluish purple discolourations at higher concentrations. Silicates and the balanced silicic acid are poorly bound by anionic exchanger resins, with the result that the initially bound silicates are released again by the binding of other anions after a short period of time and other silicates and silicic acid cannot be bound (“passage of silicate” or “passage of silicic acid”). In addition, silicic acid is poorly captured by conductivity meters, as it is largely present in water in a non-disassociated state. If the exchanger resin is not regenerated in time, silicic acid and silicates are no longer retained and can enter the process water, e.g. via the final rinsing. On stainless steel this results in coloured deposits in the lab washer and on the laboratory equipment.

Chloride

Chloride dissolved in the water in particular is critical as in higher concentrations (100 mg/l in neutral and alkaline or 50 mg/l in acidic cases) it can cause pitting (chlorine-induced localised corrosion) for example, even on stainless steels. Factors which contribute to chlorine-induced localised corrosion are higher temperatures, low pH values and concentration as a result of drying on.

Evaporation residue

When water evaporates, some substances contained in it remain as visible mineral residue. These may result in spotting and/or corrosion. Owing to the substances in the water, natural drinking water cannot be recommended for all process steps. Drinking water should be softened or demineralised depending on the application.

Rust particles

Apart from its natural constituents, drinking water sometimes contains rust, generally flushed from corroded pipework. During automated reprocessing this rust settles on the stainless steel surfaces of the lab washers and in certain circumstances on the laboratory equipment, where it causes rust stains (extraneous rust) and subsequent corrosion.

Sand

Sand and generally abrasive residues can block and damage all movable parts in the cleaning system, e.g. rollers, spray arms, couplings, etc.

Pyrogenic particles (non-biological origin)

Microscopically small particles of metals and plastics such as rubber abrasion can act as pyrogens.[2]

Bacteria, fungi, viruses and pyrogens

Bacteria, fungi, viruses and their degradation products (endotoxins, fragments of RNA and DNA, etc.) in the water can influence the growth of cell cultures, display pyrogenic properties or induce false positive results in microbiological investigations, e.g. water analysis.[2]

3.3 General procedures for water reprocessing

The following procedures can be applied depending on the use of the water:

Water softening

In the water softening process, the calcium and magnesium cations, which cause water hardness, are replaced by sodium ions. This does not change the conductivity of the water to any great extent and the evaporation residues are not reduced. When using softened water, the pH value can increase greatly due to the formation of sodium carbonate depending on the temperature, time and carbonate hardness in the initial water.

Demineralisation

In a demineralisation process, all mineral substances are largely removed from the drinking water. The following procedures can be employed for demineralisation:

- Distillation
- Cation and anion exchangers
- Electrodeionisation
- Reverse osmosis

Demineralisation: Cation and anion exchangers

With cation and anion exchangers, the procedure is based on an ion exchange reaction. The cation exchanger resins are charged with H^+ in the regenerated state, bind cations and release H^+ in the process. The anion exchanger resins are charged with OH^- in the regenerated state, bind anions and release OH^- in the process. The water contained has a relatively low conductivity (< 10 µs/cm). The non-ionic compounds, particles, microorganisms, silicic acid, pyrogens, etc., are not retained. In terms of the particles, microorganisms and pyrogens after the demineralisation, the quality of the water can be worse than before.

Demineralisation: Electrodeionisation

Electrodeionisation is an electrochemical process which unites electrodialysis and ion exchange. The active principle is the migration of ions in the electrical field with a multi-chamber system with cation and anion membranes. A special feature of the procedure is that the system is continually regenerated by the splitting of water molecules into H^+ and OH^-. Another advantage is that demineralised water does not come into direct contact with the actual exchange interfaces (exchanger resin) and it is largely possible to rule out contamination with particles, microorganisms and pyrogens. Because the reprocessing system is relatively expensive and sensitive and also because of its limited performance, the procedure is usually employed after reverse osmosis.

Demineralisation: Reverse osmosis

The reverse osmosis procedure is based on a membrane technology (semi-permeable membrane) in which the natural physical process of osmosis is reversed with the help of a booster pump. The retentate (concentrate) and the permeate are harvested from the feed water (drinking water). The retentate contains almost all the constituent substances of the feed water. The permeate is practically free from non-ionic compounds, particles, microorganisms and silicic acid and only contains a very small proportion of ionic residues. The conductivity following reverse osmosis depends on the system as well as on the initial conductivity and temperature of the feed water. Reverse osmosis systems achieve an average retention rate of salts of 90-99% and a residual conductivity of 10 to approx. 100 µs/cm. To reduce the residual conductivity even further, cation/anion exchanger resins with a filter or alternatively electrodeionisation is often employed downstream.

Demineralisation: Distillation

In distillation, the water is evaporated and then condensed again. The distillate is practically free from non-ionic compounds, particles, microorganisms, silicic acid and ionic compounds, contains only a very small proportion of volatile organic compounds and has a relatively low conductivity. Distillation can also be performed again (double distillation) or twice more (triple distillation) to increase the purity of the water. This reprocessing method requires a relatively large amount of energy.

3.4 Selection criteria for specific applications

The working stage of reprocessing and the area of application of the laboratory glassware and laboratory equipment are decisive for the selection of the water quality used and the water reprocessing system required. The working steps of reprocessing are divided as follows:

- Manual preparation
- Automated reprocessing: Pre-cleaning, cleaning and neutralisation
- Automated reprocessing: Rinsing, final rinsing
- Automated reprocessing: Disinfection
- Sterilisation

3.4.1 Manual preparation

After laboratory glassware and laboratory equipment are used, they are emptied, rinsed quickly and if necessary immersed in an aqueous solution with the corresponding process chemicals.

As a general rule, drinking water can be used to rinse laboratory glassware and laboratory equipment. For special applications in the field of inorganic analysis it may be necessary to use demineralised water. This avoids inorganic residues from the drinking water drying on the surfaces of the laboratory glassware and laboratory equipment. If laboratory glassware and laboratory equipment are immersed in an aqueous solution with process chemicals, the specifications of the manufacturer of the process chemicals with regard to water must be observed.

3.4.2 Automated reprocessing: Pre-cleaning, cleaning and neutralisation

Pre-cleaning, cleaning and neutralisation in automated reprocessing are performed with softened water. Based on experience in the automated reprocessing of laboratory glassware and laboratory equipment, we recommend the following guidelines:

- Total hardness: < 4°dGH
- Chloride content: < 100 mg/l

For special applications in the field of inorganic analysis it may be necessary to use demineralised water for pre-cleaning, cleaning and neutralisation.

3.4.3 Automated reprocessing: Rinsing and final rinsing

For the rinsing and final rinsing in automated reprocessing the user needs to determine which water constituent substances are critical for the use of laboratory glassware and laboratory equipment and select the necessary water quality or water reprocessing system based on the requirement profile.

The following tables offer suggestions for the selection of suitable water reprocessing procedures:

Baseline criteria	Cation/ anion exchanger	Cation/ anion exchanger with filter*	Reverse osmosis	Reverse osmosis with subsequent electrodeionisation
Visually free from stains	+	+	•	+
Sample bottles for drinking water and waste water	+	+	+	+

Baseline criteria	Cation/ anion exchanger	Cation/ anion exchanger with filter*	Reverse osmosis	Reverse osmosis with subsequent electrodeionisation
Inorganic analysis	+	+	−	+
Organic analysis	●	●	●	+
Cell and tissue cultures	−	●	●	+
Biology, microbiology and biotechnology	−	●	+	+
Pathology	+	+	●	+
Petroleum industry	+	+	●	+
Pharmaceutical industry:				
R&D	●	+	●	+
Analysis	−	●	−	+
Production	−	−	−	+
Cosmetics industry:				
R&D	●	+	●	+
Analysis	−	●	−	+
Production	−	−	−	+
Foodstuffs industry:				
R&D	●	+	●	+
Analysis	−	●	−	+
Production	−	−	−	+

*Filter: Particle filter or sterile filter and activated charcoal filter if required

\+ : Suitable (depending on requirements)

● : Suitable to some extent (depending on requirements)

− : Unsuitable

3.4.4 Automated reprocessing: Disinfection

Water quality and possible preliminary water treatment processes depend on whether the disinfection is performed at the start or finish of the reprocessing procedure. If the disinfection is performed at the start of the reprocessing procedure, the same water qualities should be used as for pre-cleaning, cleaning and neutralisation (see Section 3.4.2). If the disinfection is performed at the finish of the reprocessing procedure, the same water qualities should be used as for rinsing and final rinsing (see Section 3.4.3).

3.4.5 Sterilisation

If initial sterilisation of the contaminated laboratory glassware and laboratory equipment is required directly after use and prior to further reprocessing for safety reasons, e.g. because the goods have come into contact with highly pathogenic germs or genetically modified material, the steriliser itself, its procedures and also the media must conform with the procedural requirements.

Water being used to generate steam has to meet the criteria specified in DIN EN 285[3], Appendix B.

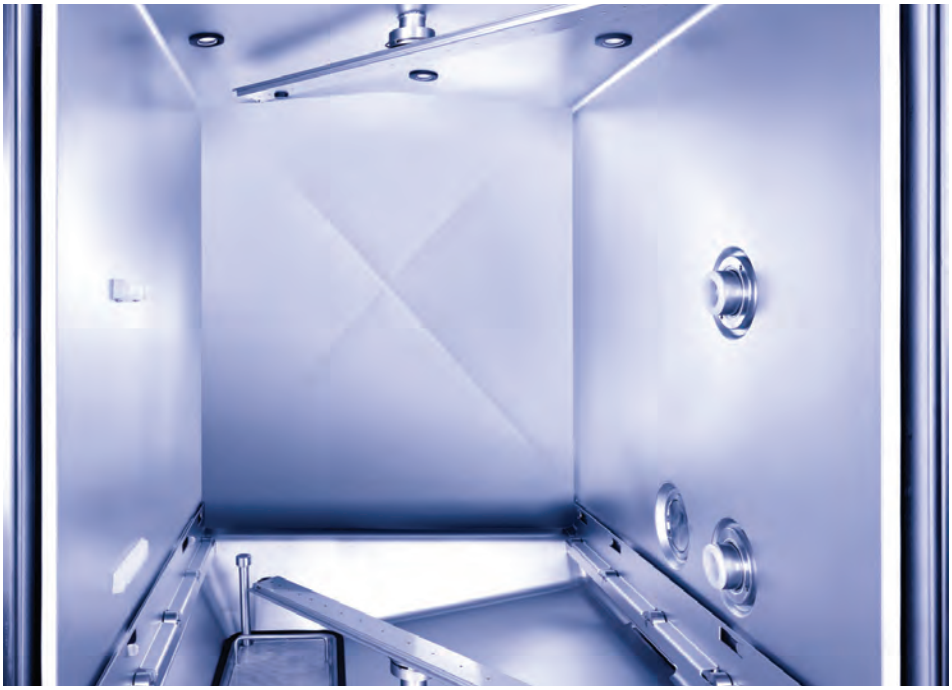
If sterilisation is performed as a part of the reprocessing process after cleaning and disinfection and prior to the next use, the steam must have appropriate features so that the use of the laboratory glassware and laboratory equipment is not affected by residues in the steam. Selection criteria may be: free from germs, free from pyrogens and analytical purity. The water being used for steam generation has to meet these criteria.

4 Lab washers

4.1 General functions

Lab washers are single-chamber units. It is a closed system in which the entire process comprising cleaning, rinsing, possibly disinfection and drying is performed.

Wash chamber of undercounter lab washer



Wash chamber of large capacity lab washer

Reprocessing in lab washers involves an aqueous process requiring water and process chemicals. The quality of the water and the correct use of corresponding process chemicals are important for this reprocessing. Softened cold or hot water is used for cleaning; the rinsing cycle uses demineralised water or ultrapure water.

Reprocessing is performed via the fresh water circulation principle, in which fresh water is used for each programme block and then completely drained off at the end of the block. When a programme starts, a defined minimum quantity of water flows into the wash chamber. This minimum quantity depends on a range of factors, for example: the size of the wash chamber, the number of loading levels, the capacity of the circulation pump and the load carriers used (cleaning via spray arms or injector nozzles).

A minimum water quantity entering the machine is required for the stable functioning of the circulation pump. Therefore the volumetric flow rate must be sufficiently high and constant.

4.2 Features and load carriers

Lab washers come in a variety of sizes which can be equipped with hinged or vertical doors and can be used as a free-standing unit or built into panelling depending on the model. Small lab washers have a hinged door, whereas the large chamber lab washers are optionally equipped with one or two doors, often vertical doors. Two-door lab washers are predominantly encountered when the reprocessing room is divided into an unclean side where the load carriers are loaded with the contaminated laboratory glassware and laboratory equipment and a clean side where the laboratory glassware and laboratory equipment are removed once the programme has finished and they can be used for analytical purposes. Depending on the size of the lab washer, the size of the chamber also varies, which determines the number of loading levels and as such the amount of laboratory glassware to be reprocessed.

Undercounter lab washer

Large capacity lab washer

The central elements of a lab washer are the cleaning system and the corresponding components such as the circulation pump, spray arms and water softener, dosing system and dryer unit. Some lab washers have additional options like conductivity metering, spray arm speed sensoring and water pressure monitoring.

Depending on the model, there are connections for cold, hot, demineralised and ultrapure water available. If hot and cold water is used, it should be softened. Smaller lab washers have an integrated softener, whereas separate softening units are required for the larger systems. Lab washers with an integrated softener have an internal reservoir for the required regeneration salt.

The number and capacity of the circulation pumps, which are used to provide the machine and load carrier spray arms with water, also depend on the size of the lab washers.

Powdered or liquid process chemicals can be used for cleaning. Generally, the powder detergent is added to a dosing compartment which is integrated in the door, whereas liquid process chemicals are pumped in with dosing pumps. Small lab washers often use peristaltic pumps for the dosing of smaller quantities, whereas larger machines often are equipped with bellows pumps or membrane pumps. The advantage of using liquid process chemicals is predominantly that the required quantity can be dosed automatically depending on the selected programme. This avoids manual underdosing or overdosing. In this case, the lab washers should be equipped with a dosage monitoring system which can be used to control whether dosage is performed (flow control) or the level of the dose applied (quantity control). In addition there are also minimum quantity controls, which measure the fill level of the canister and emit a signal or warning if the remaining quantity of process chemicals is too low.

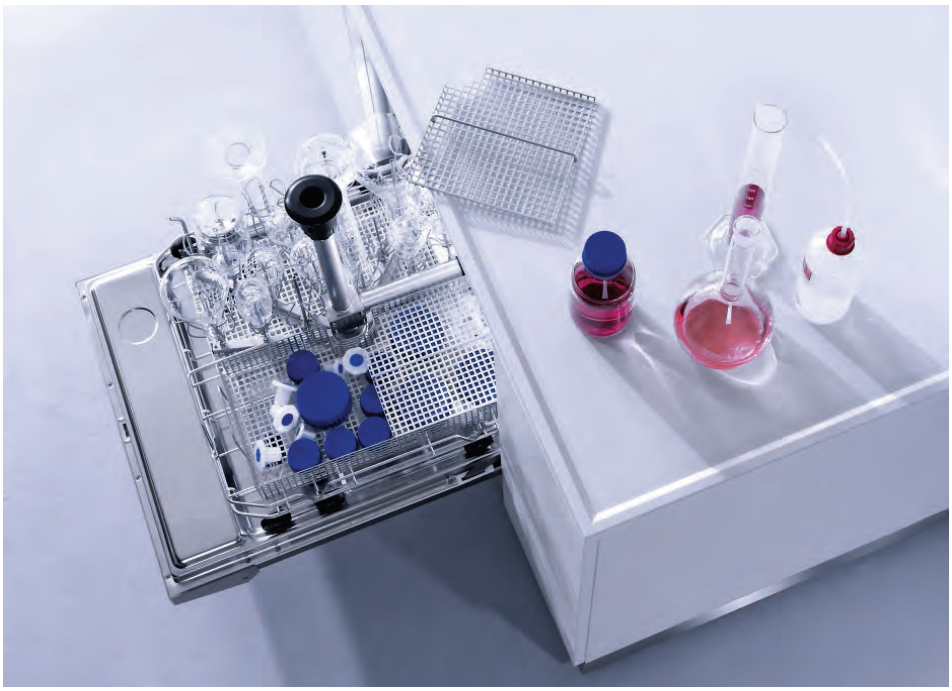
Another important component is the filter system. This should consist of a number of elements which filter both coarse and finer particles out of the rinsing liquor, thus preventing them from entering the rinsing circuit again.

Some lab washers are equipped with a dryer, which ensures that the ambient air is taken in, warmed and blown into the wash chamber to dry the laboratory glassware and laboratory equipment. This requires filtration of the room air taken in, which is done with prefilters and a high-efficiency particulare air filter (HEPA filter).

The programme cycles are controlled and monitored via the control panel during the reprocessing process. In addition, there are also interfaces on the lab washers which allow documentation of the process data via software or a printer. Depending on the model, protocols with the most important parameters such as the temperature or cycle times are output. These can then be archived and allow precise traceability and reproducibility of the processes.

Correct reprocessing in lab washers requires detailed consideration of the corresponding load carriers. There are load carriers which can be used only with one type of laboratory glassware or laboratory equipment, and there are others which allow mixed loads, such as a combination of wide neck jars and lids. Some load carriers even feature additional spray arms. These spray arms and the device's own spray arms ensure complete external cleaning and a certain degree of internal cleaning, which leaves the wide neck glassware completely clean. The cleaning of narrow neck glassware cannot be effected with just using spray arms. For a thorough cleaning of their interior parts, load carriers with injector nozzles are used.

Load carrier for narrow neck glassware



Load carrier for mixed loads

4.3 Selection criteria for specific applications

This section provides some basic information on selecting the correct reprocessing system. As the laboratory sector is very diverse, it may not be possible to apply some of this information to every laboratory one to one, but it may help to get a basic understanding of the most important aspects of reprocessing in laboratories.

When it comes to selecting the right lab washer, the first step is to define the important parameters for the respective laboratory. In this respect, one can address both constructional situations and process-relevant parameters.

The first step is for a laboratory to determine the required analytical grade, in other words the degree of cleanliness or the residual contamination which is allowed to remain on the laboratory glassware and laboratory equipment. This then dictates what equipment and features are required of the lab washer.

4

Different types of laboratory glassware

Optimal external and internal cleaning of laboratory glassware

The number and size of the lab washer depend on the quantity and size of laboratory glassware and laboratory equipment which has to be reprocessed. At the same time, it is also important to take the available space in the laboratory into account and to check whether the applications in the respective scenario require separation into infeed and outfeed areas and as such division of the laboratory into unclean and clean rooms.

The load carriers are selected based on the type and size of the laboratory glassware and laboratory equipment. In the case of wide neck glassware (e.g. beakers), cleaning with a spray arm is adequate. In the case of narrow neck glassware (e.g. round-bottomed flasks, volumetric flasks, pipettes), a load carrier with injector nozzles is required for adequate internal cleaning. The larger the laboratory glassware is, the longer the nozzle should be and the larger the diameter of the laboratory glassware, the broader the nozzle should be. This ensures that the optimal water quantity reaches the internal surfaces of the laboratory glassware. In addition, it is also important to bear the weight in mind and select a corresponding adapter or injector nozzle for cleaning larger laboratory glassware. Additional information and the selection of the correct programmes for reprocessing can be found in Section 6 “Automated reprocessing”.

5 Preparations preceding automated reprocessing

Depending on the initial condition, e.g. age, contamination, etc., of the laboratory glassware and laboratory equipment, pre-treatment may be necessary.

The following conditions can be distinguished:

- New laboratory glassware and laboratory equipment
- Contamination: Biological agents
- Contamination: Other

5.1 New laboratory glassware

It is recommended to reprocess brand new laboratory glassware and laboratory equipment before their first use with an appropriate standard procedure for the application in order to rule out any residues left over from the packaging or transport, for example.

For the biological, biotechnological and pharmaceutical sectors the recommendation is to subject the laboratory glassware to an artificial ageing procedure so that the glass surface becomes less sensitive to aqueous media. This state is achieved by filling the laboratory glassware with ultrapure water and boiling it in an autoclave (liquid programme: 121 °C, 20 mins).

5.2 Contamination: biological agents

In fields where biological agents are used, the laboratory glassware and laboratory equipment including the contamination also need to be sterilised after use and, if necessary, prior to reprocessing. Biological agents, for example as defined by the German Biological Agents Regulation (BioStoffVO) or Directive 2000/54 EC, can cause infections, sensitivity and toxic effects in humans and pose a general risk to the environment. Whether sterilisation is necessary depends on the hazard classification of the biological agents employed.

When laboratory glassware and laboratory equipment are sterilised, the contamination is partly thermally fixed, which makes is considerably more difficult to remove this debris.

5.3 Contamination: Other

Manual pre-treatment is often required before automated reprocessing. The scope of the pre-treatment depends on the soiling.
The following initial contaminants are generally observed:

- Labels and label remnants
- Silicone grease (water-soluble and non-water-soluble)
- Aqueous solutions and aqueous residues
- Hydrochloric acid and residues containing chloride
- Non-water-soluble residues
- Thermally treated organic residues
- Solvent residues
- Pipettes
- Marker labelling

Labels

Laboratories employ labels with a wide range of different adhesives. Consequently, there is no universal guideline for the removal of labels. If labels enter the lab washers, the labels and adhesive residues collect in the filter system near to the circulation pump's water intake area and may block it. The adhesive residues can also become distributed throughout the circulation pump and consequently recontaminate the laboratory glassware and laboratory equipment.

Labels should be removed prior to automated reprocessing and the adhesive residue washed off with a solvent. Alternatively, the laboratory glassware and laboratory equipment can be immersed in an alkaline surfactant solution.

Due to their organic matrix, water-soluble labels generate foam during automated reprocessing and are more difficult to remove in combination with acids.

Silicone grease

The majority of silicone greases are non-water-soluble and need to be removed with a solvent. If silicone grease enters the lab washer, it can contaminate all the laboratory glassware and laboratory equipment with silicone grease. However, some silicone greases can be removed by highly alkaline cleaning agents. Contact the manufacturer of the process chemicals for more information.

Aqueous solutions and aqueous residues

If the laboratory glassware and laboratory equipment are contaminated with aqueous solutions and aqueous residues, they should be pretreated as follows:

- Drain
- Rinse out with drinking water or demineralised water in the case of inorganic analysis
- Allow to drip dry

Hydrochloric acid and residues containing chloride

Hydrochloric acid and residues containing chloride can corrode the stainless steel of the load carriers used to hold the laboratory glassware and laboratory equipment and the chambers of the lab washer. In this case, the laboratory glassware and laboratory equipment should be pretreated as follows:

- Drain
- Rinse out with drinking water or demineralised water in the case of inorganic analysis
- Allow to drip dry well on a corrosion-resistant surface or mount
- Only place them in the racks used to hold the laboratory glassware and laboratory equipment once they are completely dry

Non-water-soluble residues

Non-water-soluble residues can be divided into two groups:

- Those that can be removed with water during automated reprocessing, e.g. crude oil, viscous oils and conditioners, etc.
- Those that cannot be removed with water during automated reprocessing, e.g. steroids, varnish and polymer residues, cracking products, etc.

The following pre-treatment has proven its worth for the first group:

- Drain and allow to drain for a long period of time
- Rinse with hot water in drinking water quality
- Allow to drip dry

The following changes should be applied for the second group:

Some varnishes and polymer residues can be removed with special process chemicals. Other residues such as steroids and cracking products should be removed from the laboratory equipment with solvents or immersed in corresponding acidic or alkaline aqueous solutions.

Thermally treated organic residues

The thermal treatment, e.g. prolonged heating or sterilisation, makes residues considerably more difficult to remove than they would have been originally. Automated reprocessing then often requires high cleaning temperatures and longer exposure times. Alternatively, if the residues cannot be removed during the automated reprocessing, the laboratory devices and laboratory equipment should be rinsed out with a solvent or immersed in corresponding alkaline aqueous solutions.

Solvent residues

Only traces of volatile and flammable solvents should be allowed to enter the lab washer, as they present a risk of fire or explosion. Other solvents can attack the plastic and elastomer components of the lab washer. The following pre-treatment has proven its worth for the use of solvents:

- Drain, allow to drip dry well and fumigate for a long period of time
- Rinse with hot water in drinking water quality
- Allow to drip dry and fumigate if necessary
- Do not store the laboratory glassware and laboratory equipment in the rinsing chamber – fill the lab washer and start the cleaning programme immediately

Pipettes

Residues can harden and crystallise in the pipette and in the tip of the pipette especially. To prevent the pipettes from becoming blocked, they should be pretreated as follows:

- Drain
- Rinse with water of drinking water quality, demineralised water or a solvent
- Immerse and store in demineralised or slightly acidic or slightly alkaline water
- Only remove them from the bath just before the automated reprocessing
- Drain
- Allow to drip dry

Marker labelling

Test runs in an automated procedure have shown in general that, depending on the dyes used, blue and green writing is easier to remove than red and black.

Marker is often removed from glass surfaces with highly alkaline process chemicals at high temperatures (≥ 80 °C) during automated reprocessing. To prevent glass corrosion, measuring instruments such as volumetric flasks, measuring cylinders, etc., should be reprocessed at lower temperatures. If the writing cannot be removed at lower temperatures, the laboratory glassware should be immersed in an alkaline, surfactant solution or wiped off with a solvent. Marker generally does not come off plastic surfaces in automated reprocessing. Special solutions are well-known on the market. Alternatively, the surface can be wiped with a solvent.

6 Automated reprocessing

The fundamental objectives of automated reprocessing are:

- **Re-use of laboratory glassware and laboratory equipment**
- **Standardisation of the processes**
- **Preservation of value of laboratory glassware and laboratory equipment**

The results of reprocessing must be good enough that the subsequent use of the laboratory glassware and laboratory equipment is not affected by the previous use or the reprocessing process itself. Acceptance criteria such as how “clean” or “analytically clean” the laboratory glassware and laboratory equipment need to be, must be determined specifically for each application for assessment of the result.

Process standardisation makes it possible to achieve consistent reprocessing results. Process standardisation is what makes the process validation viable. Standardised reprocessing is an essential prerequisite for subsequent processes such as the sterilisation.

Defined reprocessing, e.g. defined positioning of the laboratory glassware and laboratory equipment during reprocessing and defined process parameters, makes it possible to preserve the value of the laboratory glassware and laboratory equipment. Not only the financial value, but also the function of pipettes, volumetric flasks, measuring cylinders, etc. are important aspects.

In addition to the features of the lab washer, the following aspects of automated reprocessing are important:

- Positioning of laboratory glassware and laboratory equipment
- Reprocessing process

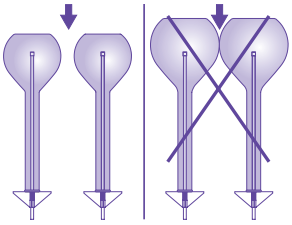
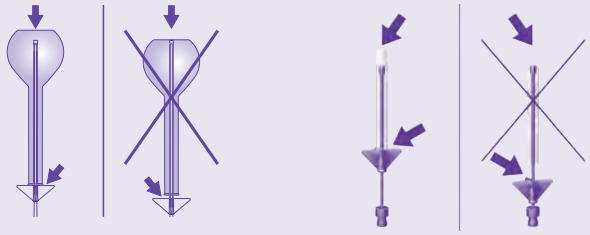
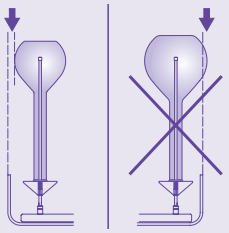
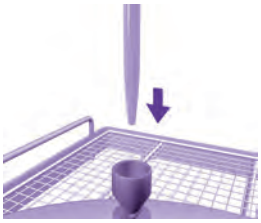
6.1 Positioning of laboratory glassware and laboratory equipment

The cleaning system must ensure that water reaches all external and internal surfaces of laboratory glassware and laboratory equipment. In this context, the positioning of the laboratory glassware and laboratory equipment depending on their shapes and contamination is of particular importance.

In lab washers, water is sprayed onto the internal and external surfaces of the laboratory glassware and laboratory equipment using specific nozzles. The external surfaces are generally sprayed by rotating spray arms. Depending on the shapes and contamination, the internal surfaces are sprayed by rotating spray arms or injector nozzles.
A general rule of thumb is:

- Rotating spray arms are adequate for the spraying of internal surfaces if the laboratory glassware and laboratory equipment have a wide opening and are not too tall, e.g. beakers, Petri dishes, mortars, watch glasses, wide neck Erlenmeyer flasks, wide neck laboratory bottles, low measuring cylinders, etc.
- Injector nozzles which extend into the laboratory glassware and laboratory equipment are required for spraying the internal surfaces if the laboratory glassware and laboratory equipment have a small opening and/or are relatively tall, e.g. round-bottomed flasks, narrow neck Erlenmeyer flasks, volumetric flasks, tall measuring cylinders, vials, etc.
- Injector sleeves in which the laboratory glassware and laboratory equipment are inserted for spraying of the internal surfaces if the laboratory glassware or laboratory equipment has a small opening and is long and thin, e.g. pipettes.
- Despite their impractical shape, test tubes with light contamination can be reprocessed with rotating spray arms and those with higher contamination with injector nozzles.
- Very small and narrow laboratory glassware and laboratory equipment such as vials need to be reprocessed with injector nozzles as the capillary forces make it necessary to enforce the water exchange in the laboratory glassware and laboratory equipment.

General rules for loading a load carrier with laboratory glassware and laboratory equipment:

Avoid spray shadows.	• Do not pack the load carriers too densely with the laboratory glassware and laboratory equipment. • Place small components such as stoppers, lids, spatulas, etc. with no overlaps if possible, in lockable trays or alternatively on perforated trays / mesh grids and cover them with a lid or net.
Avoid hollows.	• Place lids in one layer with the opening facing down.
Weigh down light laboratory glassware and laboratory equipment if necessary.	• Cover with a lid / cover net.
Avoiding blocking the spray arms.	• Laboratory glassware and laboratory equipment should be placed on the load carrier in such a way that they do not extend below or too high above the load carrier.
Prevent the laboratory glassware and laboratory equipment from toppling over.	• Place laboratory glassware and laboratory equipment on corresponding mounts/holders or injector nozzles, with a lock if necessary – Fill up the segments of test tube holders completely with test tubes.
If possible, the laboratory glassware and laboratory equipment should not touch each other.	
The injector nozzles should not touch the bottom of the laboratory glassware and laboratory equipment.	
In the case of bottles, volumetric flasks, etc. the tip of the injector nozzles should extend into the “body” region and not stop in the neck area.	• In the case of too short injector nozzles, place laboratory glassware and laboratory equipment on longer injector nozzles.
The laboratory glassware and laboratory equipment should not extend over the edge of the load carrier.	
The tip of the pipette should be placed in the injector sleeve.	

6.2 Sinner's circle

Sinner's circle goes back to the surfactant chemist Herbert Sinner (1900-1988 in Hilden). Despite all the changes and developments in automated reprocessing, the mechanism of action of Sinner's circle continues to apply. In general it visualises the interplay of the fundamental factors for a reprocessing process.

- Mechanics
- Chemistry (process chemicals)
- Temperature
- Time

Mechanics:

The employment of mechanics loosens the bonding forces between the soiling and the surface, which makes the contamination easier to remove. The mechanics, e.g. pressure and distribution of the spray jet, the shearing forces of flowing water and the surging of the circulated water, have the following effect on the cleaning results:

- Covering of all external and internal surfaces of laboratory glassware and laboratory equipment with water
- Detaching of the contamination from the surface of the laboratory glassware and laboratory equipment

Process chemicals:

The process chemicals support the reprocessing process by:

- dissolving and dissolution of the contamination from the surface of the laboratory glassware and laboratory equipment (e.g. via chemical degradation)
- binding the contamination in the circulated water (e.g. suspending or emulsifying it)

Temperature:

Temperature is an important cleaning parameter and influences cleaning due to the following properties:

- Physical processes (e.g. melting of solids such as wax, lowering of viscosity of oils, increasing of water solubility, etc.)

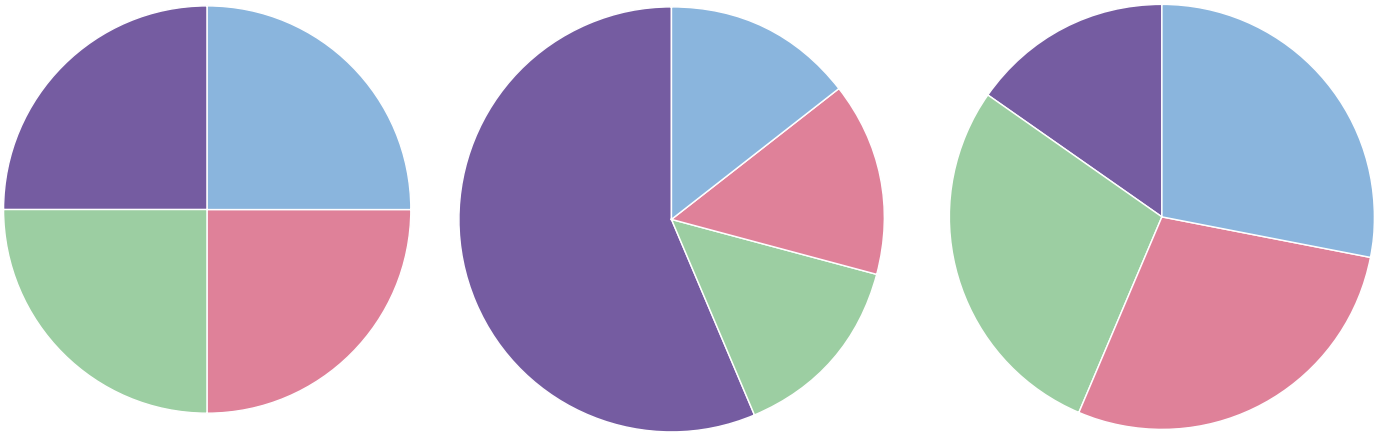
- Speed of chemical processes (e.g. acceleration of chemical reactions, etc.)

The selection of the optimal cleaning temperature plays an important role for the contamination to be removed. For example, if pre-cleaning has not been performed, a cleaning temperature which is too high will denature the proteins, making cleaning more difficult.

Time:

The time (exposure time) influences the degree of implementation of the physical and chemical processes.

Sinner's circle illustrates how the factors named are mutually dependent and that their respective sizes may differ. The “whole sum” for a defined cleaning result, however, always remains constant (illustrated by a circle). For example, if the **temperature** is increased, the **mechanics**, concentration of **process chemicals** or the **exposure time** can be reduced to achieve the same result.



In modern reprocessing processes the water employed is viewed as an additional process parameter, because the water quality can affect the cleaning success. For example, softened water is sometimes replaced partly or completely with demineralised water for cleaning in order to avoid undesirable factors such as the precipitation of the water hardness or the introduction of ionic water constituent substances. Sinner's circle is restricted to the relative interactions of the known

factors in terms of the removal of contamination. The effect of the selected factors on laboratory glassware and laboratory equipment is not taken into consideration. For example, high temperatures combined with high doses of highly alkaline cleaning agents can cause glass corrosion. In this case, the temperature and process chemicals factors must be reduced and the other factors increased.[4]

6.3 Reprocessing process

The reprocessing process comprises the following stages:

- Cleaning
- Neutralisation
- Rinsing
- Disinfection if necessary
- Drying

The necessary phases and parameters for successful reprocessing processes are combined to reprocessing programmes and these can be found on the controller of a lab washer. The programmes comprise several programme blocks (e.g. pre-cleaning, main cleaning, neutralisation, etc.), which are performed one after another in the course of the programme. Each programme block is composed of one or more programme steps (e.g. water supply, dosing of process chemicals, heating, exposure time at programmed temperature, etc.), which are performed one after another in the course of the programme block. The programmes can be modified in accordance with the device manufacturer's instructions.

6.3.1 Cleaning

The aim of cleaning is to remove the adhering contamination from the surfaces of laboratory glassware and laboratory equipment, using process chemicals if necessary, and to expel it from the lab washer. The following mechanisms are possible:

- Detachment by means of a chemical reaction, e.g. simple dissolving in water, reaction with acidic, alkaline or oxidising process chemicals
- Dissolution and emulsification, e.g. oils, fats, etc.
- Dissolution and suspension, e.g. particles, soot, pigments, etc.

Cleaning may comprise one or several programme blocks, e.g. pre-cleaning, cleaning, etc. The order of the cleaning blocks should take the chemical and physical properties of the contamination into consideration. Chemical reactions between the process chemicals and the contamination during cleaning must be avoided as they can cause precipitation of the contamination or even fixation of the contamination to the surfaces of the laboratory glassware and laboratory equipment, e.g. alkaline treatment of metallic salt residues and amines or acidic treatment of fatty acids. Examples of application-specific cleaning:

- Protein: pre-cleaning with cold water first, then hot alkaline cleaning
- Metallic salts: warm acidic pre-cleaning first, then hot alkaline cleaning
- Oils, waxes: warm alkaline cleaning first, if necessary employing surfactants or emulsifiers (> softening temperature), then hot alkaline cleaning (> softening temperature)

6.3.2 Neutralisation

The aim is to neutralise the residues of the process chemicals employed on and in the surfaces of laboratory glassware and laboratory equipment. As the last stage of cleaning is often performed with alkaline process chemicals, acidic chemicals are generally used for neutralisation.

6.3.3 Rinsing

The aim of rinsing is to remove the remaining dissolved / detached contamination and the process chemical employed from the surfaces of laboratory glassware and laboratory equipment and to expel it from the lab washer.

Rinsing can be composed of one or more programme blocks. The sequence of the rinsing blocks, e.g. 1x drinking water, 2x demineralised water or 3x ultrapure water, should take the subsequent use into consideration. With the exception of the last rinse (final rinsing), the rinses (intermediate rinses) are usually performed with cold water. If process chemicals with surfactants are used for cleaning, it may be necessary to use hot water for one or more of the intermediate rinses (> cloud point of the surfactants) in order to expel any foam from the lab washer more efficiently. The final rinse is usually performed at a higher temperature in order to kill off any germs in the water (≥ 70 °C) and support the subsequent drying.

6.3.4 Disinfection

Disinfection is only required if the safety classification in the laboratory demands it. The aim of disinfection is to reduce the number of pathogenic germs and active viruses on the surfaces of laboratory glassware and laboratory equipment and, if applicable, to reduce the contamination to a degree which is accepted as being safe (kill off or disable).
The disinfection parameters depend on the different types of germs and viruses.

Possible disinfection procedures:

- Thermal disinfection (for thermostable laboratory glassware and laboratory equipment)
- Chemo-thermal disinfection (for thermolabile laboratory glassware and laboratory equipment)

Possible time of disinfection:

- First programme block:
  Objective: Disinfection of laboratory glassware and laboratory equipment and contamination / waste water
  Disinfection procedure: thermal disinfection or chemo-thermal disinfection
- Following pre-cleaning or cleaning:
  Objective: Disinfection of laboratory glassware and laboratory equipment
  Disinfection procedure: generally chemo-thermal disinfection
- Last rinse:
  Objective: Disinfection of laboratory glassware and laboratory equipment
  Disinfection procedure: thermal disinfection

6.3.5 Drying

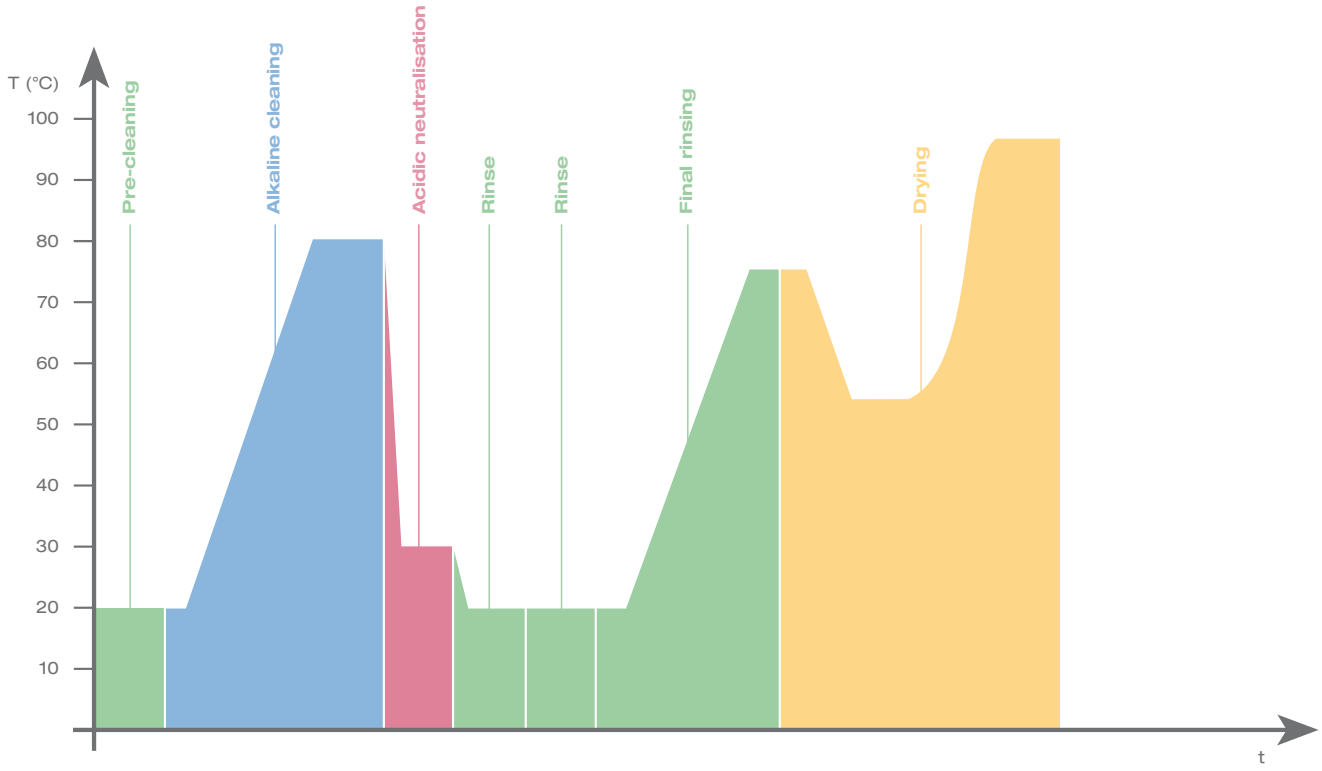
The aim of drying is to remove the water from the surface of laboratory glassware and laboratory equipment and from the chamber of the lab washer.

6.3.6 Examples of temperature/time diagrams

This section outlines three different typical programmes, which are assigned to different applications in Section 6.4 “Selection criteria for specific applications”.

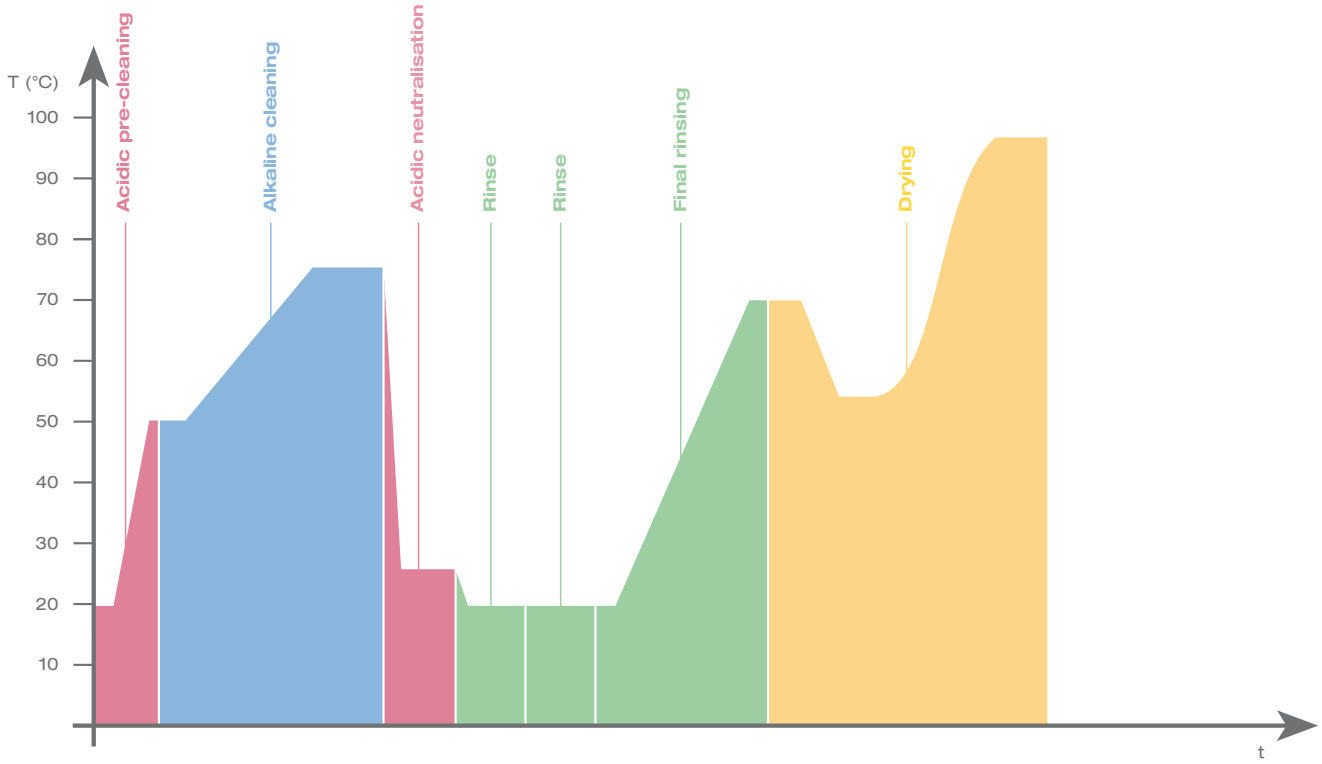
Type A:

- **Pre-cleaning:** Cold water, without heating, without process chemicals
- **Cleaning:** Cold / hot water, with heating, with alkaline cleaning agents
- **Neutralisation:** Cold / hot water, without heating, with acidic neutralisers
- **Multiple rinses:** Cold / hot water or demineralised water / ultrapure water, without heating
- **Final rinsing:** Demineralised water / ultrapure water, with heating
- **Drying**



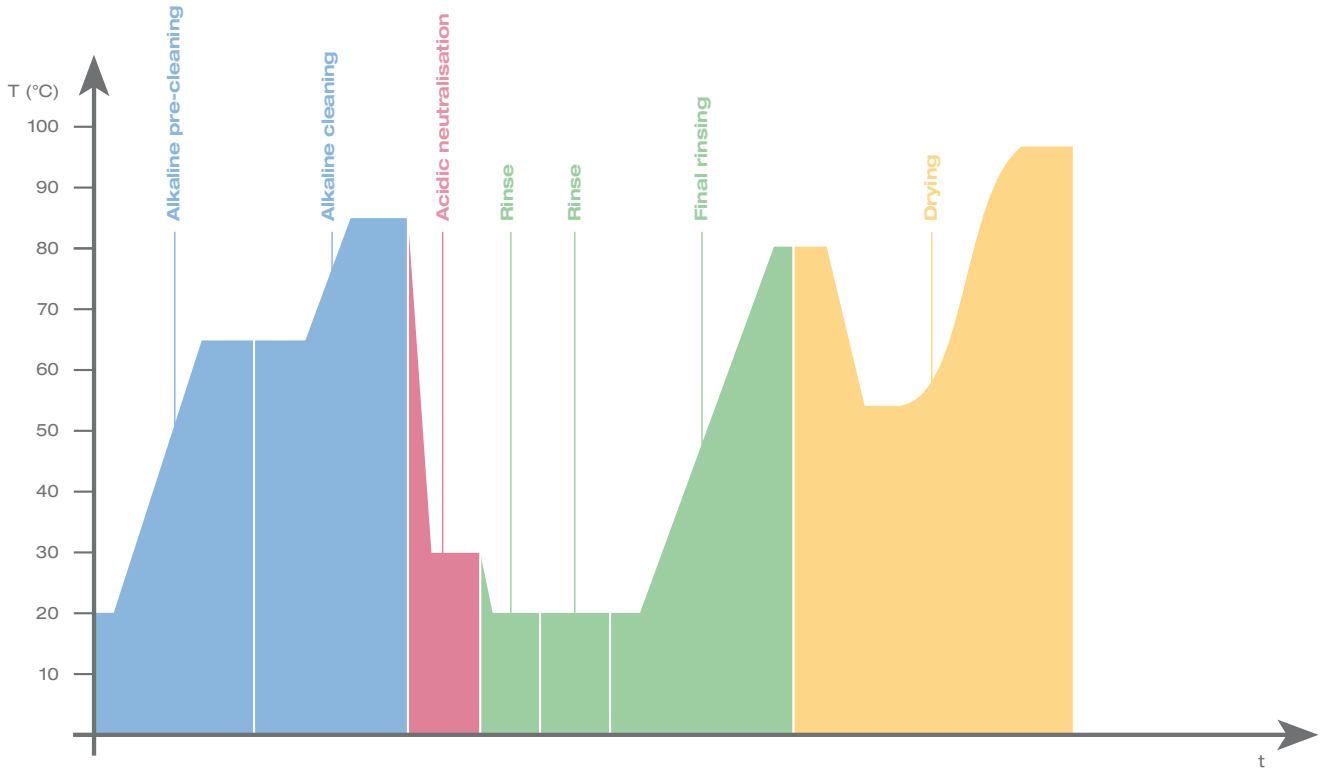
Type B:

- **Pre-cleaning:** Cold water, with heating, with acidic cleaning agents
- **Cleaning:** Cold / hot water, with heating, with alkaline cleaning agents
- **Neutralisation:** Cold / hot water, without heating, with acidic neutralisers
- **Multiple rinses:** Cold / hot water or demineralised water / ultrapure water, without heating
- **Final rinsing:** Demineralised water / ultrapure water, with heating
- **Drying**



Type C:

- **Pre-cleaning:** Cold / hot water, with heating, with alkaline cleaning agents
- **Cleaning:** Cold / hot water, with heating, with alkaline cleaning agents
- **Neutralisation:** Cold / hot water, without heating, with acidic neutralisers
- **Multiple rinses:** Cold / hot water or demineralised water / ultrapure water, without heating
- **Final rinsing:** Demineralised water / ultrapure water, with heating
- **Drying**



6.4 Selection criteria for specific applications

The following table offers basic recommendations for the type of programmes depending on the application:

Area	Contaminant	Reprocessing process
General	Contamination generally easily soluble in water	Type A
	Marker labelling	Type A
	Label remnants	Type A or type C
Water and environmental analysis	Limescale and algae	Type B
	Inorganic analysis	Type B
	Organic analysis	Type A or type C
	Microbiological analysis	Type A
	Agar	Type C
	Culture media	Type A or type B
Petroleum industry	Crude oil, mineral oils	Type C
Cosmetics industry	Creams, ointments	Type C
Foodstuffs industry	Inorganic analysis	Type B
	Organic analysis	Type A or type C
	Microbiological analysis	Type A
Biology, microbiology, biotechnology	Cell and tissue cultures, if necessary sterilised	Type A or type C
	Agar	Type C
	Culture media	Type A or type B
	Organic residues, if necessary sterilised	Type A or type C

Area	Contaminant	Reprocessing process
Pathology	Paraffin wax	Type C
Hospital laboratory	Non-coagulated blood	Type A
Blood bank	Non-coagulated blood	Type A

The general types of programme need to be adapted to the application in detail, e.g. temperatures, process chemicals, water qualities, etc. Examples:

Application	Reprocessing process	Programme adaptation
Agar	Type C	Pre-cleaning: - without process chemicals - with heating to approx. 90-93 °C
Paraffin wax	Type C	Pre-cleaning and cleaning: - hot water - heating to approx. 65-75 °C 1. Rinsing: - hot water
Pipettes, volumetric flasks, measuring cylinders	Type A	Due to possible glass corrosion: Cleaning: - heating to max. 70-75 °C - mildly alkaline cleaning agents - as low as possible concentration of process chemicals

7 Inspections

7.1 Removal of laboratory glassware and laboratory equipment and final visual inspection following automated reprocessing

Visual inspection of laboratory glassware following automated reprocessing

After removing the laboratory glassware from the lab washer, the laboratory glassware is inspected with regard to optical cleanliness (e.g. no residues), degree of drying and damage. After the inspections, usable laboratory glassware is stored free from dust in corresponding laboratory cabinets until its next use.

In particularly sensitive fields like microbiology, genetic research and ultra-trace analysis, personnel must wear sterile disposable gloves when removing the laboratory glassware items from the load carriers of a lab washer. This ensures that the glasses are not subjected to fat residues or particles of skin.

Visible deposits on laboratory glassware and laboratory equipment indicate that the reprocessing process has not been successful. The reasons for the deposits must be determined before the next reprocessing process and resolved definitively. Laboratory glassware and laboratory equipment with adhering deposits must be reprocessed again.

Insufficiently dried laboratory glassware should be completely dried in a drying cabinet at 100 °C.
Defective laboratory glassware should be collected in the intended containers and then disposed of accordingly.

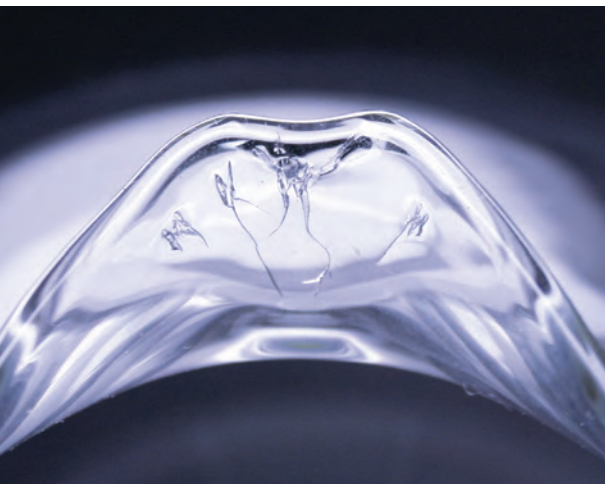
7.2 Visual inspection before using laboratory glassware

Before they are used, laboratory glassware must be inspected by the laboratory personnel to ensure that they are clean without any residues and do not display any damage. In this process, a distinction is made between glass features which occur during the glass production process and are unavoidable and have no effect on the function of the laboratory glassware and the safety of the personnel and superficial damage such as cracks, conchoidal fractures, impacts, etc.

Superficial damage can be caused by the improper use of laboratory glassware and occurs during the reprocessing process if simple rules such as those applicable to the loading of the load carriers are not followed.

As soon as there are doubts about the unrestricted reuse of laboratory glassware, the glassware should be taken out of circulation for safety reasons and disposed of professionally. There are collection bins available in laboratories for this purpose.

The most frequently reported damage is chipping in the neck, edge and thread regions of the laboratory glassware. This often results in sharp edges and presents an avoidable risk of injury. In the case of delicate laboratory glassware with lateral branches and valve stopcocks, improper handling can also cause breakages and splintering. Improper transport and incorrect storage or reprocessing of laboratory glassware can cause chipping and impacts. When assessing laboratory glassware before using it, it should ideally be held up to a bright light source in order to identify damage or undesirable deposits.



Cracks in the spout of a laboratory beaker

Glass abrasion in normal conditions is usually so low that the laboratory glassware can be used without any restrictions without ageing. In contrast, the ceramic ink used to indicate the contents specification, product brand, graduation / scale and other information can discolour depending on the number of reprocessing cycles, exposure time and process chemicals employed. The basic rule of thumb applies: if the graduation is only barely or no longer legible at all, the laboratory glassware is lacking an essential function. As such, it should be replaced with a new item.

8 Sterilisation of laboratory glassware and laboratory equipment

Depending on the degree of germ reduction required, laboratory glassware and laboratory equipment must be thermostable at up to 134 °C. Once they have been appropriately cleaned and taking their thermostability into account they should be sterilised in a steam sterilisation procedure at temperatures between 120 °C and 134 °C. Depending on their later use, laboratory glassware can also be sterilised in hot-air sterilisers at temperatures of up to 250 °C.

With steam sterilisation the exposure times are between 3.5 mins at 134 °C and 20 mins at 120 °C. Depending on the model of the sterilisers, temperatures of up to 140 °C can also be selected for special purposes, e.g. for prion inactivation (CJD/vCJD). As a basic principle, the sterilisation temperature is predominantly based on the thermostability of the laboratory glassware and laboratory equipment. In cases of repeated use, laboratory glassware and laboratory equipment are used taking their application and sterilisability into consideration.

The steam sterilisation procedures should be selected with either single or multiple ventilation of the sterilising chamber and the laboratory glassware and laboratory equipment depending on the properties and shapes of the laboratory glassware and laboratory equipment. Porous laboratory glassware and laboratory equipment with complex shapes and hollow areas are sterilised in the fractionated prevacuum procedure, solid laboratory glassware and laboratory equipment in the simple prevacuum procedure.

Dishes, beakers, non-sealed and unfilled bottles and similar containers should be placed in the sterilising chamber in such a way as to allow the condensation that forms during the procedure to run off. This ensures that the vessels are dry when removed and largely avoids evaporation residues remaining on surfaces.

The sterilisation of liquids in open or in sealed containers must only be performed in sterilisers which are particularly suited to this purpose and using specially designed sterilisation procedures. Due to the risk of delayed boiling, these sterilisers and procedures must ensure that the temperature of the liquids has been reduced to max. 80 °C when the sterilising chamber is opened.

Whether laboratory glassware and laboratory equipment needs to be packaged is primarily dependent on the application conditions and on the storage period until the next use. As a basic principle, the decision must be taken for all laboratory glassware and laboratory equipment as to whether packaging is necessary to avoid recontamination.
The storage period of the laboratory glassware and laboratory equipment until they are next used should be taken into consideration.
The laboratory glassware must not be packaged when the hot-air sterilisation procedure is used.

9 Storage of reprocessed laboratory glassware

As not all laboratory glassware is used again directly after successful reprocessing, it needs to be properly stored in the interim. For this reason, there must be sufficient dust-free, lockable storage cabinets and drawers available in the laboratory.

It is important that the laboratory glassware is stored dry and at a consistent temperature between 20 °C and 30 °C. Direct exposure to sunlight must be avoided.

After reprocessing the glassware to be stored should be removed from the lab washer and taken to its place of storage as soon and directly as possible.

Corresponding containers and baskets should be used to transport the laboratory glassware from the lab washer to the respective place of storage for safety reasons.

When placing the items in the laboratory cabinet, special attention must be given to the fact that the laboratory glassware is placed in the corresponding cabinets steadily and without any impacts. Sufficient distance between the items should be selected so as to guarantee that the items can also be removed in the future without any impacts. Under no circumstances should laboratory glassware be stacked on or in each other.

In addition, it is also important to leave a sufficiently large distance to the door of the cabinet. The door should not come into contact with the stored laboratory glassware when it is opened or closed. The doors should be opened and closed slowly and carefully.

Laboratory glassware with large openings like beakers is stored with the base pointing upwards in order to avoid possible contamination from settling dust.

Bottles with threaded tops should ideally be stored with a plastic cap loosely screwed on in order to avoid damage to the glass thread.

When storing reagent bottles and other laboratory glassware which is sealed with a ground stopper, it must be ensured that a strip of paper is placed between the stopper and where it is inserted for the period of storage in order to prevent the stopper from getting stuck.

10 Reprocessing rooms in laboratory buildings

Reprocessing rooms – the different requirements and solutions shown here are just as varied as the uses of the laboratories themselves.

In small or very old laboratories in particular, the reprocessing room also referred to as the “scullery” is limited to a laboratory sink with a draining board. As such, the most important elements are available: water for cleaning and air for drying the laboratory glassware and laboratory equipment. However, to take the burden off the laboratory personnel and protect them from injuries (glass breakages) and contaminations, it is practical to use lab washers.

Lab washers can be used in the laboratory for a specific area, for a single floor or centrally for a complete department or building. The versions have different costs and also depend on the personnel concept.

Efficient laboratory lab washers with an integrated drying system can be installed under a work bench in laboratories. The devices are then directly available and can be started as needed. Depending on the requirements, the laboratory personnel can also set special programmes for situations when less glassware and equipment has to be reprocessed. This decentralised version requires a large number of lab washers which are not used to their maximum capacity. However, it excludes a carryover, for example from synthesis areas to trace analysis. No additional personnel is required for the transport and cleaning logistics.

In biological laboratories in particular the laboratory glassware and laboratory equipment must be autoclaved before reprocessing. After cleaning and disinfection the goods are sterilised in a hot-air steriliser. A laboratory-specific reprocessing procedure is mostly not practical for these types of application.

Laboratory bench with undercounter lab washer

Transport trolley for laboratory glassware and laboratory equipment

In addition to the investment costs for the devices, the set-up space and the removal of heat and odours are the main reasons against reprocessing laboratory glassware and laboratory equipment in the laboratory. For this reason, separate, ventilated and cooled rooms are created, which, being workrooms, require daylight. A special reprocessing room can be used jointly by a department or a whole floor in a laboratory, which is why it is worth investing in larger devices. Special personnel should be employed to run this reprocessing room – also because this frees up the highly-qualified laboratory personnel. The personnel can also collect the laboratory glassware and laboratory equipment in the laboratories and return them to the laboratory after reprocessing. The horizontal transport is performed with transport trolleys, for example. The trolleys should be equipped with watertight tubs and should be parked under the workstations when not in use.

The continuous further development of this concept is the centralisation of reprocessing and the associated functions. The reprocessing room and media kitchen as well as the autoclave rooms are compiled in one area. Trained personnel perform all the tasks that concern the provision of laboratory glassware and laboratory equipment and media. Capacity calculations are used to define the right quantity and size of the lab washers needed in the laboratory. In big laboratories with centralised reprocessing areas large chamber lab washers can be installed. In this operating concept their use is considerably more efficient and thus fewer devices are required. Automatic dispensing of process chemicals is the most practical solution for a central reprocessing room.

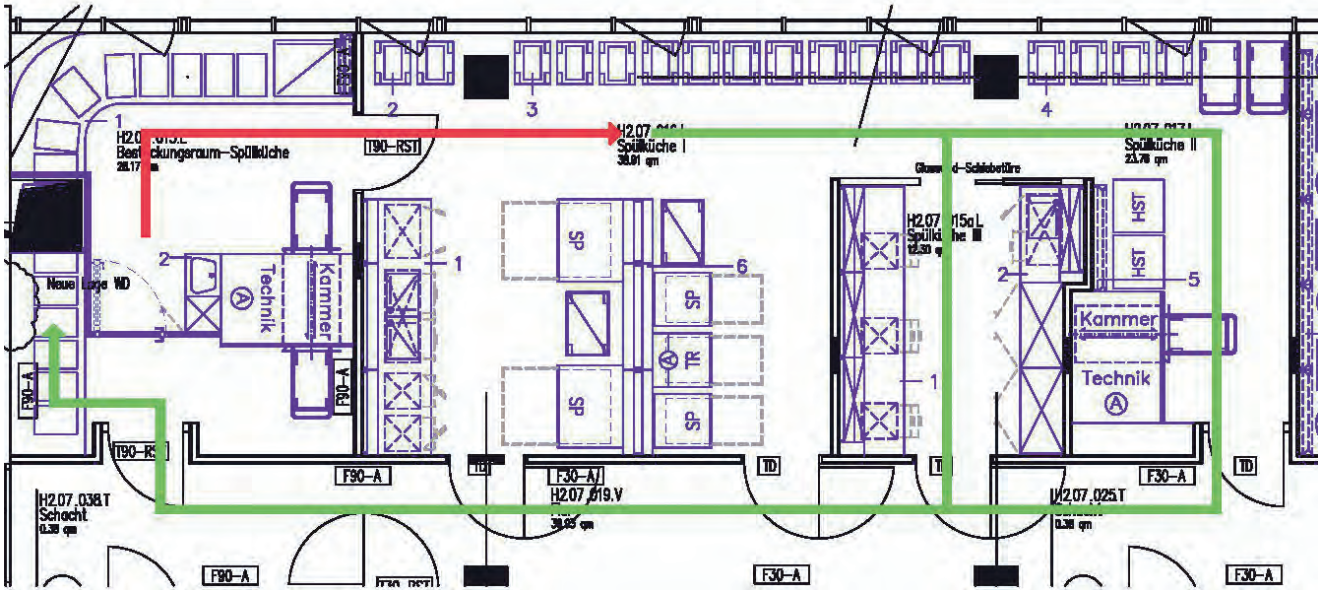
The redundancy of the necessary devices is ensured in the central reprocessing room and staff cover guaranteed. The investment, operational and maintenance costs of a central reprocessing room are considerably lower than those of decentralised versions.

Central laboratory reprocessing room

Example for the changeover from a decentralised to a central reprocessing room

Initial situation	Concept for central reprocessing rooms
18 reprocessing rooms	3 reprocessing rooms
20 rooms (for the autoclaving of media and waste)	12 rooms (for the autoclaving of media and waste)
33 large capacity lab washer	12 large capacity lab washer
13 pipette cleaning units	–
18 steam sterilisers 400 l	6 steam sterilisers 400 l
11 hot-air sterilisers	6 hot-air sterilisers

A standardised, certifiable process is required for the reprocessing of laboratory glassware and laboratory equipment. It is essential for the quality of reprocessing to prevent material flows from crossing and to ensure that there are sufficient working and storage spaces available.



Logistic flow in a reprocessing room

Unclean material

Clean material

Logistics flow in central reprocessing room

- Delivery via transport box system
- Autoclaving of laboratory glassware and laboratory equipment
- Cleaning of laboratory glassware and laboratory equipment
- Sterilisation of laboratory glassware and laboratory equipment
- Distribution of reprocessed laboratory glassware and laboratory equipment with transport box system

Outfeed side of a transport box system

However, the combination of the devices means that logistics is taking on ever more significance in the building. If horizontal distribution of the laboratory glassware and laboratory equipment is still possible with transport trolleys, vertical distribution via cargo lifts would cause excessively long waiting times. In recent years, small goods transport systems connecting the individual floors have proven their use for this purpose.

There is an equipment room on every floor in which the laboratory glassware and laboratory equipment are handed over and collected in transport boxes.

The distribution system for the central reprocessing room can also connect multiple reprocessing system rooms in larger buildings and supply the building. Additionally, the transport systems can also be used to distribute samples, media and consumables and to dispose of waste.

When planning an optimal reprocessing room, the different requirements of users and building owners need to be taken into account, as, just as when it comes to the laboratories themselves, there is never only one correct solution. When changes are made to the laboratory building, be they renovations, refurbishments or new buildings, the opportunity should be seized to optimise the entire logistics chain in the building. Intensive determination of the requirements forms the basis for a forward-looking operating concept in this context.

Glossary

Analytical grade

Degree of cleanliness or admissible residual contamination on laboratory glassware and laboratory equipment. The analytical grade is determined in the respective laboratory.

Borosilicate glass 3.3

Type of glass with very high chemical and temperature resistance. Borosilicate glass 3.3 has the following composition (in per cent by weight): 81% SiO_2, 13% B_2O_3, 3.5% Na_2O, 0.5% K_2O and 2% Al_2O_3

Chemo-thermal disinfection

Process in which disinfection is achieved via the effect of process chemicals (disinfectants) with a defined concentration, at a defined temperature and for a defined period of time.

Cloud point

Temperature at which a non-ionic surfactant solution (1 g/100 ml) turns cloudy. The cloud point is also dependent on the surfactant concentration.

Colloids

Particles / droplets which are very finely distributed throughout a dispersion medium (gas, liquid, solid). The particles are so finely distributed that they do not settle on the bottom due to gravity, collect or clump together.

Cracking products

Smaller fragments of long hydrocarbons, which are produced in crude oil processing when long hydrocarbons are broken down into small pieces.

DIN EN 60672-3, Type C110

This standard defines the parameters for porcelain laboratory ware.

DIN ISO 3585

This international standard defines the parameters for a type of glass designated as borosilicate glass 3.3.

Disinfection

Process whereby the number of viable microorganisms on surfaces is reduced to a defined level, so that laboratory glassware and laboratory equipment is safe to handle and use for the following application.

Dispersion	Heterogeneous mixture in which one substance is finely distributed in another substance. There are different dispersions such as emulsions, foam, suspensions, aerosols, etc.
Dissociation	The automatic ability of molecules to split into ions or atoms, for example.
Emulsion	Heterogeneous mixture in which one liquid is finely distributed in another liquid.
Endotoxins	Decomposition products of bacteria. Endotoxins are very thermally stable and can even survive sterilisation.
Fouling	Humic acids accumulate in the ion exchanger and cannot be removed. The blocking of the exchange groups reduces the efficiency of the ion exchanger.
Fused quartz	Type of glass with outstanding chemical and temperature resistance. Fused quartz is made up of 100% SiO_2. The very high melting points makes the production of fused quartz very expensive.
Inertness	Property of a substance which prevents chemical interaction with a potential reaction partner.
Liquid programme	Standard programme for the sterilisation of liquids.
Load carrier	Stainless steel frames in which laboratory glassware and laboratory equipment can be set or laid and then loaded into the lab washer's chamber. They are often referred to as racks, baskets, inserts, etc.
Pathogenic germs	Organisms which can cause illness.

Glossary

Pyrogens

Substances with inflammatory effects with a wide range of origins. If drugs are injected, for example, included pyrogens can provoke fever in the human body. Pyrogens have biological effects in even the smallest of quantities.
A distinction is made between endogenous and exogenous pyrogens. The endogenous pyrogens are produced by the body itself (e.g. interleukins), whereas exogenous are divided into the following categories:

1. Bacterial pyrogens (e.g. bacterial endotoxins)
2. Viral pyrogens (components of viruses)
3. Fungal pyrogens (components of fungi)
4. Pyrogens of non-biological origin, such as microscopic particles of plastic or rubber abrasion, etc.

This booklet focuses on exogenous pyrogens.

Reprocessing

Process in which the used laboratory glassware and laboratory equipment are returned to a condition in which they can be used again for a subsequent application.

Soda-lime glass

Type of glass with high thermal expansion and which is used for by far the largest quantity of all industrially produced glasses. Typical soda-lime glass has the following composition (in per cent by weight): 71-75% SiO_2, 12-16% Na_2O, 10-15% CaO

SOP (standard operating procedure)

Work instructions which describe the procedure within a process (here reprocessing process).

Spray shadows

Areas of a lab washer chamber or load carrier where objects prevent the spray jet from reaching the surfaces of laboratory glassware and laboratory equipment.

Sterilisation

Process in which all viable microorganisms are removed from the laboratory glassware and laboratory equipment.

Suspension	Heterogeneous mixture in which a solid is finely distributed in a liquid.
Thermal disinfection	Process in which disinfection is achieved by the effect of a high temperature for a defined period of time.
Water hazard class	Classification of different substances which boast a different potential in terms of the pollution of water. The substances which are potentially hazardous to water are divided into three classes: WHC 1 = low hazard to waters WHC 2 = hazard to waters WHC 3 = severe hazard to waters

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